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# Effect of body position on gas exchange in patients with unilateral pleural effusion: influence of effusion volume

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The objective of this study was to evaluate the effect of lateral body position on gas exchange in patients with unilateral pleural effusion, with special reference to the influence of effusion volume.

Thirty consecutive patients with unilateral pleural effusion, without evidence of parenchymal pulmonary involvement, were entered into the study.

Arterial blood gas tensions ($PaO_2$, $PaCO_2$) were randomly measured in both right and left lateral decubitus body positions, while breathing room air. To assess the influence of the effusion volume, roentgenographic and functional parameters were used. Among the latter, FVC, $FEV_1$, TLC and RV were determined. The influence of the presence or absence of pleuritic pain on gas exchange was also assessed.

There was no significant difference in $PaCO_2$ between right and left lateral decubitus body positions ($31{\cdot}1 \pm 4{\cdot}2$ *vs.* $31{\cdot}0 \pm 4{\cdot}5$ mmHg). The differences in $PaO_2$ between the two body positions ranged from 0·5–25 mmHg (mean $9{\cdot}3 \pm 6{\cdot}6$ mmHg). Mean $PaO_2$ with the normal-side (control) down ($PaO_2$-N) ($81{\cdot}4 \pm 8{\cdot}5$ mmHg) was higher, but without significant statistical difference, than mean $PaO_2$ with the effusion-side down ($PaO_2$-E) ($78{\cdot}0 \pm 12{\cdot}5$ mmHg). $PaO_2$-N was higher than $PaO_2$-E in 22 of 30 patients (conventional), and lower in eight patients (paradoxical). No consistent relationship was found for alterations in $PaO_2$ in different positions with the volume of effusion, either when estimated by a roentgenographic method or when using spirometric or plethysmographic values. The mean difference between $PaO_2$ values in the two positions ($\Delta PaO_2$ N-E) ($6{\cdot}3 \pm 9{\cdot}8$ mmHg) in patients with chest pain was significantly greater ($P<0{\cdot}05$) than the $\Delta PaO_2$ N-E in patients without pain ($-3{\cdot}3 \pm 10{\cdot}7$ mmHg). Moreover, only pleuritic chest pain showed a significant statistical influence on $\Delta PaO_2$ N-E, when all factors were analysed simultaneously.

Although gas exchange is improved in most patients in the lateral decubitus position with normal-side down, some patients behave paradoxically. This difference does not appear to be related to the effusion volume, but seems to be influenced by the presence of pleural pain.

## Introduction

Gravity can be used to improve gas exchange in patients with unilateral lung disease, if such patients are positioned so that the good lung is gravity dependent (1–3). Reversal of this gravitational advantage has seldom been observed in adult patients (4,5), although it may be the rule in infants (6).

In patients with unilateral pleural effusions, the $PaO_2$ decreases most when they are positioned such that the less-ventilated lung, compressed by pleural fluid, is in the dependent position (7,8).

Recently however, Chang *et al.* (9) found that eight of 21 patients with unilateral pleural effusions had higher values of $PaO_2$ when they were positioned in the lateral decubitus position, with the effusion-side down. They concluded that the volume of the effusion was the main determinant of gas exchange behaviour, and that this paradoxical change will take place when the pleural effusion is large enough. Although they failed to find a consistent relationship between effusion volume estimated by chest roentgenograms and alterations in $PaO_2$ during different positions, they did find a high correlation between these alterations and volumes estimated by spirometry.

The main purpose of the present study was to evaluate the effect of effusion volume on the behaviour of gas exchange in different decubitus positions.

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Roentgenographic and functional criteria were used and among the latter, TLC and RV were included, variables that have not been evaluated in previous studies.

## Materials and Methods

Thirty-three consecutive patients with unilateral pleural effusions without clinical, roentgenographic or bronchoscopic evidence of bronchopulmonary disease were studied. All participants signed informed consent forms approved by the Institutional Committee on Human Research. Three patients were later excluded due to lack of compliance with the adoption of decubitus positions, progressive contralateral lymphangitic carcinomatosis and the development of bilateral effusion.

The mean age of the remaining 30 patients, 15 men and 15 women, was $44{\cdot}6 \pm 22{\cdot}3$ years (range 16–85 years). Final diagnoses are presented in Table 1, the aetiology of the effusion remaining unknown after a mean follow-up of 2 years in five patients.

As in previous studies (7–9), the volume of the effusion, assessed roentgenographically, was graded as 'small' when the fluid contour was seen just above the costophrenic angle, as 'large' when the effusion occupied at least one-half of the hemithorax, and 'medium' when the level of fluid was between these two. The presence of pleural effusion was confirmed by thoracocentesis and were exudates according to the criteria of Light *et al.* (10). The presence of pleuritic chest pain was carefully evaluated in every patient.

A sample of arterial blood, with the patient breathing at room air, was drawn from an indwelling arterial line 15 min after the right lateral and left lateral decubitus positions were adopted in random order. The blood was drawn anaerobically in heparinized syringes, and was immediately analysed for $PO_2$, $PCO_2$, and pH at 37°C in appropriate electrodes (ABL-2, Radiometer, Copenhagen, Denmark).

After blood gas analyses were completed, forced flow–volume loops were performed on the erect position in all patients, a minimum of three suitable recordings obtained and the best one used. Plethysmographic determination of static volume was carried out in 26 patients and single breath pulmonary diffusion in 24 patients. All functional determinations were performed using a Master-Lab assembly, Jaeger, Germany. The reference values were according to those of the European Community for Coal and Steel (11).

All invasive diagnostic procedures were delayed until postural and functional studies were completed.

After demonstrating a normal distribution of all parameters in this study using the Kolgomorov–Smirnov test, the gas tensions of blood samples taken in the right and left lateral positions were compared by the matched paired *t*-test. The relationship between changes in $Pa\text{O}_2$ in different positions and pulmonary function parameters was analysed using the linear correlation coefficient. The effect of effusion volume (graded by chest roentgenogram) and pleuritic chest pain on pulmonary function parameters and alterations in $Pa\text{O}_2$ with decubitus was examined by one-way analysis of variance (ANOVA). To assess the influence of several factors simultaneously, we used an ANOVA with the $\Delta Pa\text{O}_2$ N-E as the dependent parameter, the radiologically determined effusion volume and the presence of pleuritic pain as factors, and FVC, $FEV_1$, RV and TLC as covariables. For all analyses, statistical significance was defined as $P<0{\cdot}05$.

## Results

There was no significant difference in $Pa\text{CO}_2$ between right and left lateral decubitus positions ($31{\cdot}1 \pm 4{\cdot}2$ *vs.* $31{\cdot}0 \pm 4{\cdot}5$ mmHg). The values of $Pa\text{O}_2$ differences between the two lateral decubitus positions ranged between 0·5–25 mmHg (mean $9{\cdot}3 \pm 6{\cdot}6$ mmHg). Mean $Pa\text{O}_2$-N ($81{\cdot}4 \pm 8{\cdot}5$ mmHg) was higher, but without significant statistical difference, than mean $Pa\text{O}_2$-E ($78{\cdot}0 \pm 12{\cdot}5$ mmHg) (Fig. 1). $Pa\text{O}_2$-N was higher than $Pa\text{O}_2$-E in 22 (conventional) of 30 patients and lower in eight patients (paradoxical). The mean $Pa\text{O}_2$ on the normal-side was similar in conventional ($81{\cdot}0 \pm 9{\cdot}0$ mmHg) and paradoxical patients ($82{\cdot}4 \pm 7{\cdot}3$ mmHg). However, on the effusion-side, mean $Pa\text{O}_2$ in conventional patients ($72{\cdot}4 \pm 9{\cdot}0$ mmHg) was significantly lower ($P<0{\cdot}001$) than in paradoxical patients ($93{\cdot}4 \pm 6{\cdot}1$ mmHg) (Fig. 2).

Roentgenographically, the pleural effusion was 'large' in eight patients, 'medium' in 10 patients and 'small' in 12 patients. Mean results of spirometric and plethysmographic parameters are shown in Table 2. We found no consistent relationship between the roentgenographic size of the effusions and alterations in $Pa\text{O}_2$ between different positions ($r = -0{\cdot}16$). We did not find consistent correlations between spirometric or plethysmographic volumes (% of predicted) and gasometric changes with decubitus (Table 3). We did find a significant ($P<0{\cdot}05$) negative influence of effusion volume graded by chest roentgenogram on functional volumetric parameters.

Twenty-one of 30 patients complained of pleuritic pain during evaluation. The mean $\Delta Pa\text{O}_2$ N-E

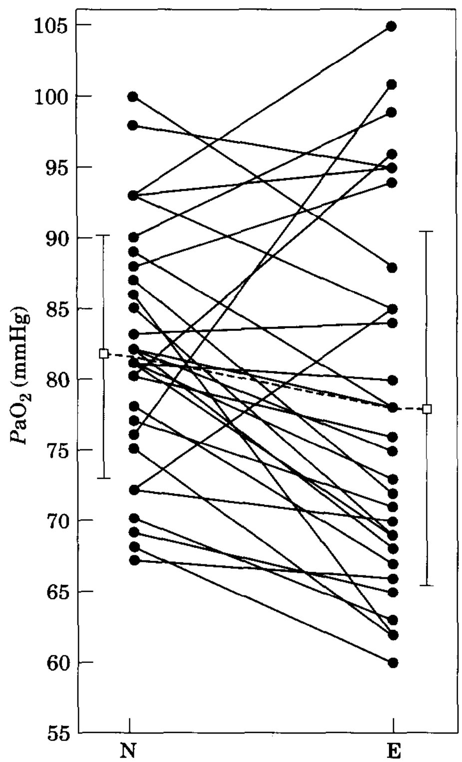


*Fig. 1* Changes in $PaO_2$ between two lateral decubitus positions (N, normal-side down; E, effusion-side down). The values of $PaO_2$ differences range from 0·5–25 mmHg. Mean $PaO_2$-N was higher, but without significant statistical difference, than mean $PaO_2$-E. □, Mean ( ± SD) value.

*Table 1* Cause of pleural effusions

| Cause | No. | % |
|---|---|---|
| Tuberculosis | 11 | 36·7 |
| Malignancy | 8 | 26·7 |
| Collagen diseases | 4 | 13·3 |
| Empyema | 2 | 6·7 |
| Unknown | 5 | 16·6 |
| Total | 30 | 100 |

(6·3 ± 9·8 mmHg) in patients with chest pain was significantly greater ($P$<0·05) than the $\Delta PaO_2$ N-E in patients without pain ( − 3·3 ± 10·7 mmHg).

When analysing the effect of multiple factors on $\Delta PaO_2$ N-E, only the presence of pleuritic chest pain showed a significant statistical influence ($P$<0·05).

## Discussion

These results confirm that the difference in $PaO_2$ values between right and left lateral decubitus positions in patients with unilateral pleuropulmonary disease is generally considerable (mean 9 mmHg) (1). However, $PaCO_2$ did not change between positions, indicating that the change in $PaO_2$ was not a consequence of a change in overall ventilation.

Three previous studies (7–9) have been conducted to assess the relationship between lateral decubitus

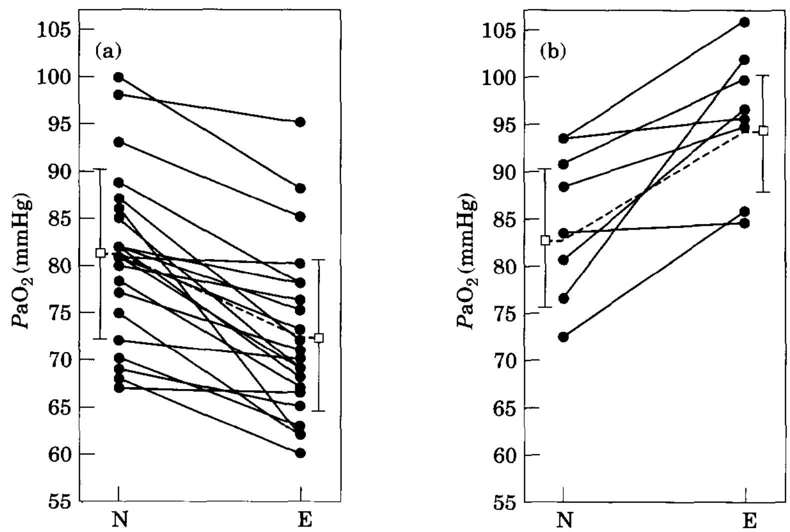


*Fig. 2* Changes in $PaO_2$ between two lateral decubitus positions (N, normal-side down; E, effusion-side down) in (a) 22 conventional ($PaO_2$-N>$PaO_2$-E) and (b) eight paradoxical patients ($PaO_2$-N<$PaO_2$-E). While the mean $PaO_2$-N was similar in both groups of patients, the mean $PaO_2$-E in conventional patients was significantly lower ($P$<0·001) than in paradoxical patients. □, Mean ( ± SD) value.

*Table 2* Results of lung function tests*

| | Small | Medium | Large | Total |
|---|---|---|---|---|
| FVC | 75·7 ± 18·9 | 63·1 ± 24·0 | 46·7 ± 15·9 | 63·8 ± 22·7 |
| $FEV_1$ | 70·3 ± 16·1 | 62·7 ± 24·4 | 48·9 ± 19·8 | 62·1 ± 21·3 |
| TLC | 76·3 ± 14·6 | 72·0 ± 19·2 | 59·0 ± 15·9 | 70·8 ± 17·4 |
| RV | 86·6 ± 20·2 | 86·0 ± 23·0 | 74·9 ± 24·3 | 83·7 ± 21·8 |
| RV/TLC | 113·6 ± 19·7 | 123·2 ± 24·4 | 128·3 ± 33·1 | 120·3 ± 24·5 |

Mean ± SD, *Values are expressed as % of predicted value.

*Table 3* Correlation coefficients between $\Delta PaO_2$ N-E and functional parameters

| Functional parameter* | *r* | No. patients |
|---|---|---|
| FVC | 0·17 | 30 |
| $FEV_1$ | 0·17 | 30 |
| RV | −0·10 | 26 |
| TLC | −0·01 | 26 |
| RV/TLC | −0·26 | 26 |

*Values are expressed as % of predicted value.

positions and arterial oxygenation in patients with unilateral or asymmetrical pleural effusions.

In the first two studies (7,8), a deterioration of the ventilation–perfusion rate was observed in all patients when the effusion was gravity-dependent, although this effect was less marked in patients with large effusions.

The influence of the effusion volume on gas exchange seems to be indirectly confirmed by the results of Chang *et al.* (9). These authors did not find any consistent relationship between the effusion volume and alterations in $PaO_2$ between different positions, but they did find that the $PaO_2$-N was higher than $PaO_2$-E in patients with a mild to moderate reduction of $FEV_1$ and FVC, whereas the reverse applied in the patients with a moderate to severe reduction of $FEV_1$ and FVC.

As in the study by Chang *et al.* (9), and in contrast with the findings of Sonnenblick *et al.* (7) and Neagley and Zwillich (8), we observed that although most of our patients improved with the normal lung dependent on gravity, a significant proportion (eight of 30 patients) showed higher values of $PaO_2$ with the effusion lung down. However, in contrast with the findings from Chang *et al.* (9), we did not find any correlation between the magnitude of differences in $PaO_2$ values on different decubitus positions and the effusion volume, either when estimated by a roentgenographic method or when using spirometric values. Furthermore, TLC, considered the most accurate estimation of lung volume, did not show any significant correlation with the changes in $PaO_2$ between decubitus positions. On the other hand, our results show an agreement in the quantification of the effusion volume when estimated by roentgenographic or functional methods. These results do not validate the suggestion made by Chang *et al.* that the $FEV_1$ and FVC predict the effusion volume more accurately than the chest roentgenogram. Since both studies were almost identical in design, it is hard to explain these differences, other than to note that the study by Chang *et al.* (9) contained a higher proportion of 'large' effusions, without including any patient with a 'small' effusion.

Potential mechanisms by which lateral decubitus on the effusion-side could improve $PaO_2$, remain to be established. Chang *et al.* (9) hypothesized that 'large' pleural effusions may have a greater impact on perfusion, decreasing blood flow to the affected side even if this side is gravity-dependent, thus diminishing the mismatching between ventilation and perfusion. In contrast, when the patients lie on the lung without pleural effusion, a compressive effect on the dependent normal lung exerted by the contralateral side effusion may induce ventilation–perfusion mismatch, because gravity increases perfusion to the normal lung which is a less well-ventilated lung. This hypothesis can not explain the present results, because we did not find any consistent relationship between the effusion volume and alterations in $PaO_2$ between different positions.

As mean $PaO_2$ when patients lay on the side of the healthy lung was similar in both groups of patients (conventional and paradoxical), it seems that mechanisms responsible for different behaviour between groups act mainly while patients lie on the effusion lung side.

A loss of alveolar units, always present when a parenchymal disease is the cause, is far from being demonstrated in the lung with the effusion. In a study performed in six seated subjects with unilateral pleural effusion, without other radiographic abnormality, Anthonisen and Martin (12) observed that the distribution of Xenon 133 boluses inhaled slowly from residual volume was the same on the side with the effusion as on the healthy side. These findings were compatible with effective static pleural pressure being the same on both sides. Although the presence of fluid reduced the volume of aerated lung at the base, the authors tentatively concluded that the pleural effusions displaced basal regions but did not reduce regional expansion or increase airway closure. Keeping the airspaces intact and to some extent, the capacity to ventilate preserved, patients lying on the effusion lung side depend on effort to take advantage of a position in which a presumed diminished perfusion would facilitate matching between ventilation and perfusion.

Pleural pain is characteristically sharp and associated with inspiration and movements of the chest wall. When it is severe, the patient breathes in short grunts and may attempt to splint the appropriate part of the chest by holding it or lying on it (13). Based on our findings that patients with pain showed a positive and significantly greater $PaO_2$ N-E difference than patients without pain, we postulate that the presence of pain may help to explain the different behaviour between conventional and paradoxical patients. Patients with painful pleural effusions will tend to provoke a regional hypoventilation through restraining the expansion of the dependent hemithorax while lying on the effusion side. On the other hand, patients without pain may breath deeply in this position taking advantage of the potential aforementioned mechanisms.

Should our reasoning be valid, patients with painful pleural effusions and severely reduced $PaO_2$ may benefit from generous use of analgesic drugs while lying on the affected side.

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